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a.i.s.e. Investigation of hot metal ladles,July 12, 1946

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PRELIMINARY OUTLINE OF PROPOSED TEST PROGRAM

A. I. S. E.

INVESTIGATION OF

HOT METAL LADLES

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at

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1. Purpose of Investigation - This investigation has been established by the A.I.S.E. to determine, through research and tests, the strength behavior of hot metal ladles and to evolve, on this basis, rational design theories and formulae.

The proposed program includes the consideration of welded and riveted ladles. The detailed program will cover the effects of various numbers and sizes of stiffener rings; also variable length trunion pins.

One or more models will consist of the frustrum of a cone with a side slope of one inch per foot and a depth of molten metal the same as the average diameter. Other models will consist of the frustrum of a cone in which are inserted two pieces of flat, one on each side, comparable to a prototype having thirty inches of flat. All of the models will be based on a prototyte of 150-ton capacity.

The test program includes measurement of strains and deflections due to static load. The important problems involving stresses due to temperature differentials will not be considered.

2. Ladle Design - A consideration of the size of model, quantities of material to be used in the loading, the size of the test equipment, etc., indicates that a model of about 1-1/2 ton size would be suitable for this program. This would be a model of 1/100 size in volume and of about 1/5 size in diameter and height of ladle.

Four specimens are proposed: one of riveted construction and three of welded construction. The literature indicates that by fabricating the ladles of welded steel plates, the weight may be reduced by over one-third. For this reason only one specimen is to be made of the riveted type construction.

It is proposed that the models include the brick lining. One specimen will be tested both with and without the lining to determine its effect upon the stresses in the ladle. If this shows that the effect of the lining is negligible it can then be eliminated in further tests.

The four specimens have been designed by the methods now usual in practice, with modifications as required by the test procedure and program. During the fabrication and test period theoretical studies will be made and these will be correlated with the test results insofar as possible.

3. Description of Specimens - The four specimens are designated A, B, C, and D. In the study of each model certain variables will be studied and considered in the design of the specimen. The following is a discussion of these variables.

Specimen A: (See Fig. 1). This is a riveted design. The trunion assembly and stiffening rings are bolted in place so that the size of the stiffening rings may be varied. The trunion pins on this specimen, as well as on all of the others, will be long enough to permit the moment on the trunion assembly to be varied. The sides of the unit as well as the bottom are to be flat.

Specimen B: (See Fig. 2). This is of welded construction similar to that used for a 150-ton ladle. The trunion pins are long, the sides and bottom flat, and two stiffening rings are used.

Specimen C: (See Fig. 3). This is of welded construction, simulating current design practice for 150-ton round ladles. The trunion pins are long, the bottom dished, and a center stiffening plate is used.

Specimen D: (See Fig. 4). This is another welded design. The trunion pins are long and the sides and bottom flat. The shell is extra thin and additional stiffening rings are provided.

The specimens are to be fabricated of LIGHT GAGE STRUCTURAL QUALITY FLAT HOT-ROLLED CARBON STEEL conforming to ASTM Specification A 245-44T, Grade C. The sides of the models will have a 1 to 12 slope.

4. Specimen Design - The actual stresses in the ladles are highly indeterminate due to the shape of the structure and its method of assembly. However, to design a testable unit at this time, various assumptions have been made which greatly simplify the design. Since it is essential that the actual hot metal ladles be extremely safe when in use, the basic assumptions are generally a great deal on the safe side.

The designs will be based upon the assumption that the bands and adjoining shell act as hoops to carry the full load and any other relieving effects are considered as added factors of safety.

General Data for Design.

Volume	6.9	cu ft.
Depth of Metal	24-3/4	in.
Bottom Lining	2	in.
Side Lining	1-1/2	in.
Metal Line	3	in. down
Flat on Side	6	in. wide
Loads: Metal	3000	lb.
Shell	600	lb.
Lining	500	lb.
Load per Trunion	2050	lb.

For a summary of the design of the four specimens see Table 1.

5. Test Equipment - The actual hot metal ladles are loaded with a fluid weighing approximately 435 lb per cu ft. Since it is undersirable to load the models in the laboratory with hot liquid metal it is planned to use various other materials, i.e., water, sand, a liquid with the same weight as sand to check the effect of using a granular material, iron shot, lead shot, and mercury. This series of loads will give a range both above and below that obtained in the mills with hot metal. After the laboratory tests are completed it may be desirable to make one loading of each of the ladles with hot metal, at the mills, if possible.

A supporting frame (See Fig. 5), is necessary to carry the specimen during the test operations. The usual hooks have been replaced by eye-bars which function in the same manner as the hooks and are easier to fabricate as a special unit. The movable supports have been provided so that the tests may be made in a manner very similar to the actual mill operation. To keep the eye-bars from spreading when bending begins in the trunion pins, an adjustable tie rod has been provided, also furnishing accurate center-to-center adjustment.

6. Measurements - There are various items of the ladle which may be considered in designing for strength. They are: the trunion pin, trunion assembly, stiffening rings, the side walls of the shell, and the bottom of the shell. Measurement will, therefore, be made in an attempt to determine what strains exist in each of these members when the model ladle is loaded and also whether these strains are comparable with those obtained by theoretical considerations.

Those measurements which at this time appear advisable, to obtain the desired information, are as follows:

(a) Change in shape of the ladle at the top and each stiffener ring by use of dial gages.

(b) Strains in the side walls of the shell by use of SR4 electrical strain gages.

(c) Strains in the stiffening rings by use of SR4 gages.

(d) Straing in the trunion assembly by use of SR4 gages.

(e) Strains in the bottom of the shell by use of SR4 gages.

(f) Deflections of the bottom of the ladle by use of dial gages.

Since each specimen is symmetrical about two axes, the strains need be measured in only one quadrant with an occasional check gage in other quadrants. A general lay-out of gage locations as planned, is presented in Fig. 6 to 9, inclusive. If possible, a qualitative check of the strains will be made on each specimen by use of a brittle lacquer coating to determine the point at which the strains are a maximum. This procedure may somewhat alter the gage locations as presented in Fig. 6 to 9.

7. Test Procedure - In the tests of this program each of the variables proposed by the committee will be studied. Table 2 shows the relation between these variables and the various specimens.

The procedures for studying the variables as listed in Table 2 are outlined as follows:

Specimen A

(a) The distance center-to-center of hooks shall be varied to four positions. This will be done with one loading material and each of the three stiffener sizes.

(b) The three stiffening rings shall be tested in a normal hook position and with all six loading materials.

(c) Each test in (b) shall also be conducted with the test ladle supported by the stands.

Specimens B, C, and D

(a) The distance center-to-center of hooks shall be varied to four positions, using only one loading material.

(b) The units shall be tested with the hooks in their normal position and all six loading materials used.

(c) Each test in (b) shall also be conducted with the ladles supported by the stands.

TABLE 1

SUMMARY OF SPECIMEN DESIGN

Item	Specimen A	Specimen B	Specimen C	Specimen D
Trunion pin diameter	1-1/4 in.	1-1/4 in.	1-1/4 in.	1-1/4 in.
Shell thickness	3/32 in.	3/32 in.	3/32-1/2-3/32	1/16 in.
Bottom thickness	3/32 in.	3/32 in.	1/8 in.	3/32 in.*
No. of stiffening rings	2	2	2 + band	5
Stiffener spacing	11 in.	11 in.	11 in.	6-6-6-5 in.
Stiffener size (top)	3/8 x 2-1/2	1/2 x 3/4	1/2 x 1/2	3/4 x 1/2
	3/16 x 2-1/2	---	---	---
	3/4 x 2-1/2	---	---	---
Second stiffener size	5/8 x 2-1/2	1/2 x 1-3/4	1/2 x 3/4	3/4 x 1/2
	5/16 x 2-1/2	---	---	---
	1-1/4 x 2-1/2	---	---	---
Third stiffener size	---	---	---	3/4 x 1/2
Fourth stiffener size	---	---	---	3/4 x 3/4
Fifth stiffener size	---	---	---	3/4 x 1/2

* Stiffened

TABLE 2

VARIABLES OF LADLE SPECIMENS

Specimen	A	B	C	D
Type of Construction	Riveted	Welded	Welded	Welded
Trunion Pin	Longitudinal	Longitudinal	Longitudinal	Longitudinal
Trunion Assembly	General Type bolted in place	Same type as A	Thickened band type	New design, narrow and longitudinal
Stiffening Rings	Vary size (3 sizes bolted in place	2 Rings of normal size (1 of 3 in A)	2 Rings designed with trunion	5 Rings of small size
Shell Thickness	3/32-in.	3/32-in.	3/32-in.	1/16-in.
Bottom Shape	Flat	Flat	Dished	Flat
Ladle Shape	Flat sides	Flat sides	Round	Flat sides

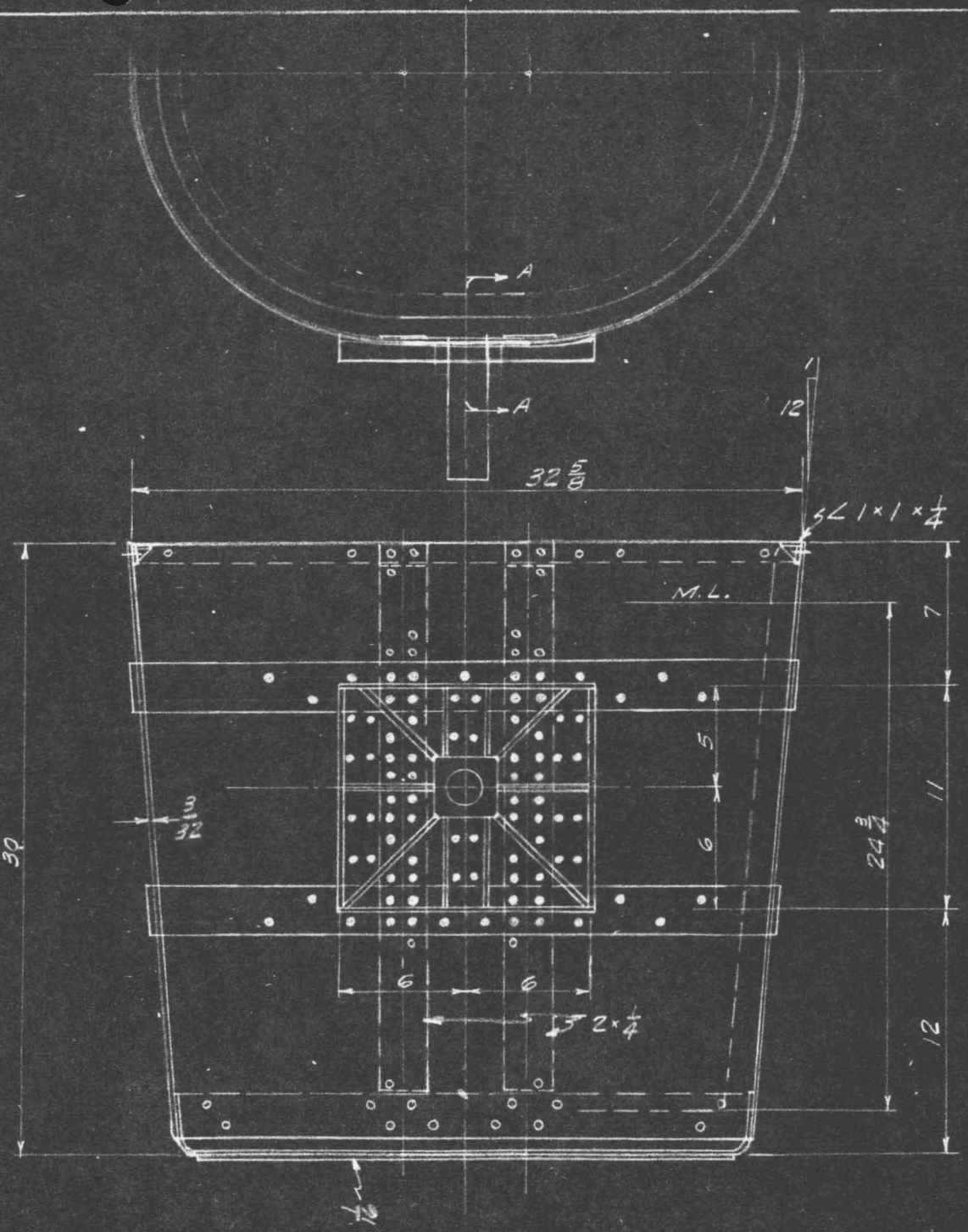
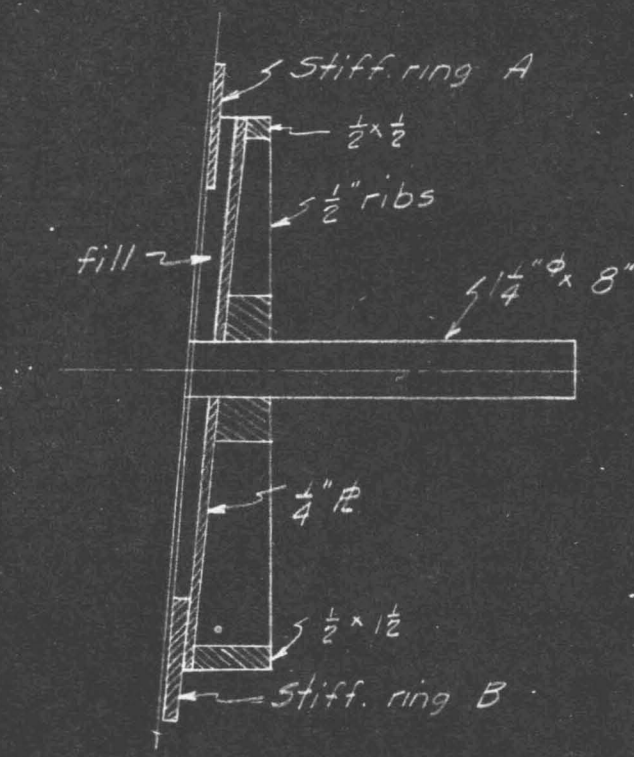


FIG. NO. 1.



SECTION A-A.

Ring	A_1 – $2\frac{1}{2} \times \frac{3}{8}$	B_1 – $2\frac{1}{2} \times \frac{5}{8}$
	A_2 – $2\frac{1}{2} \times \frac{7}{16}$	B_2 – $2\frac{1}{2} \times \frac{5}{16}$
	A_3 – $2\frac{1}{2} \times \frac{3}{4}$	B_3 – $2\frac{1}{2} \times 1\frac{1}{4}$

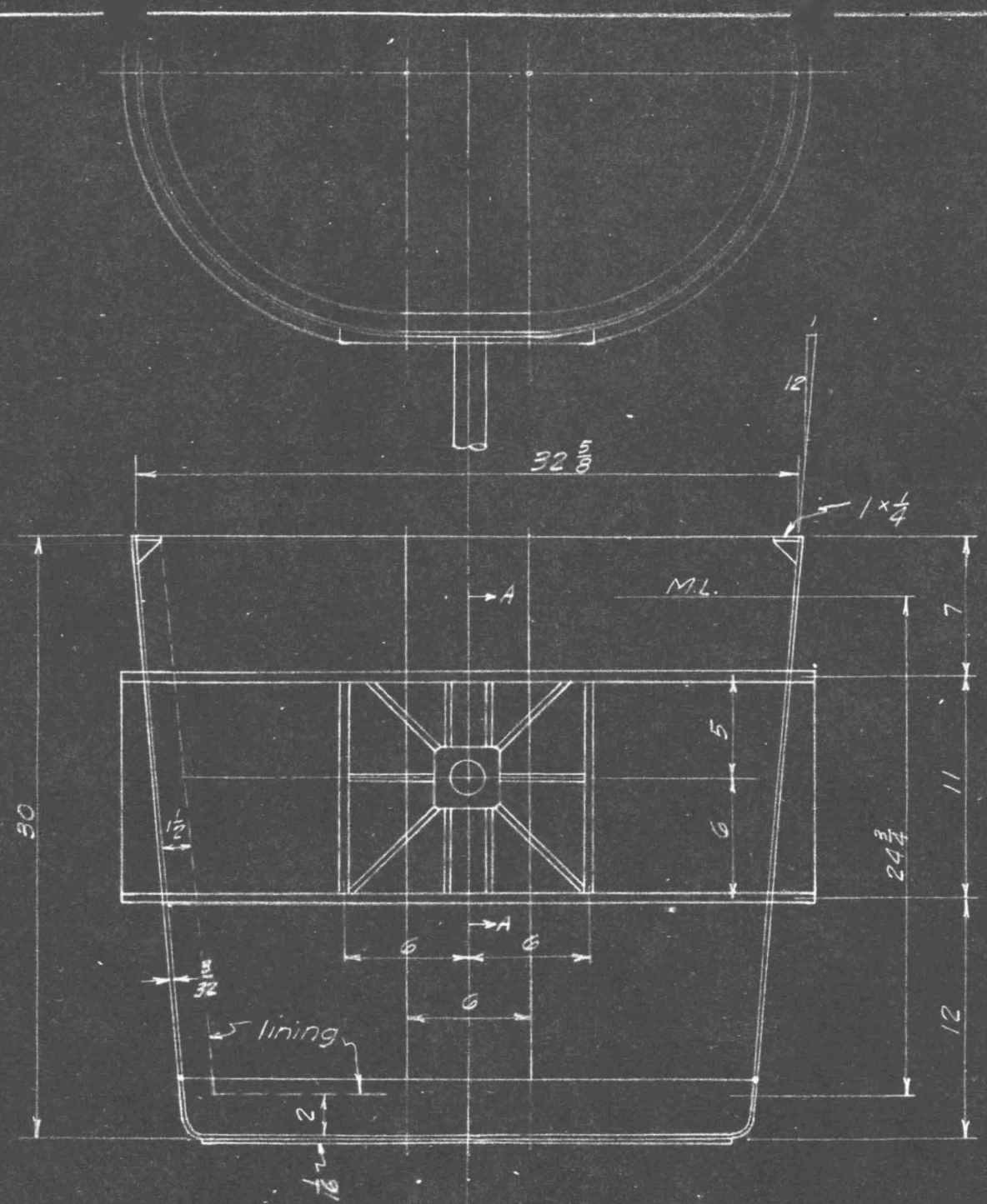
1/4" ϕ bolts & rivets

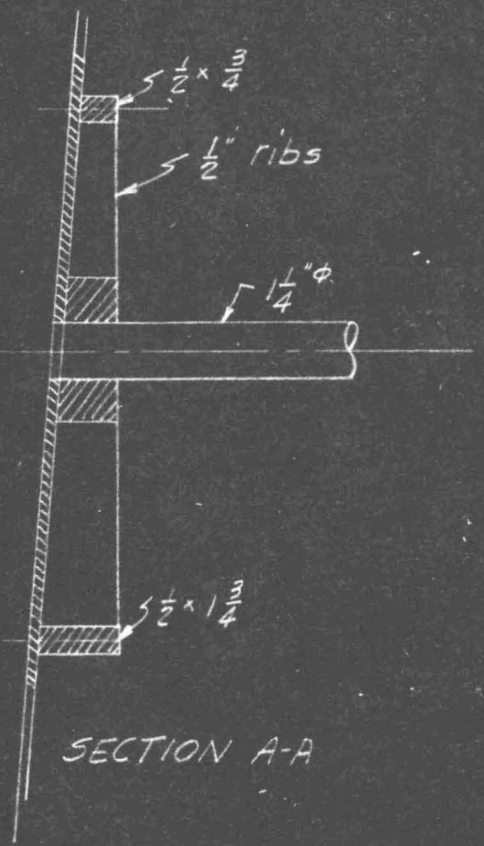
A. I. & S. E.
HOT METAL LADLES
SPECIMEN A

Scale 1/8" = 1"

WHM

FL 202.2





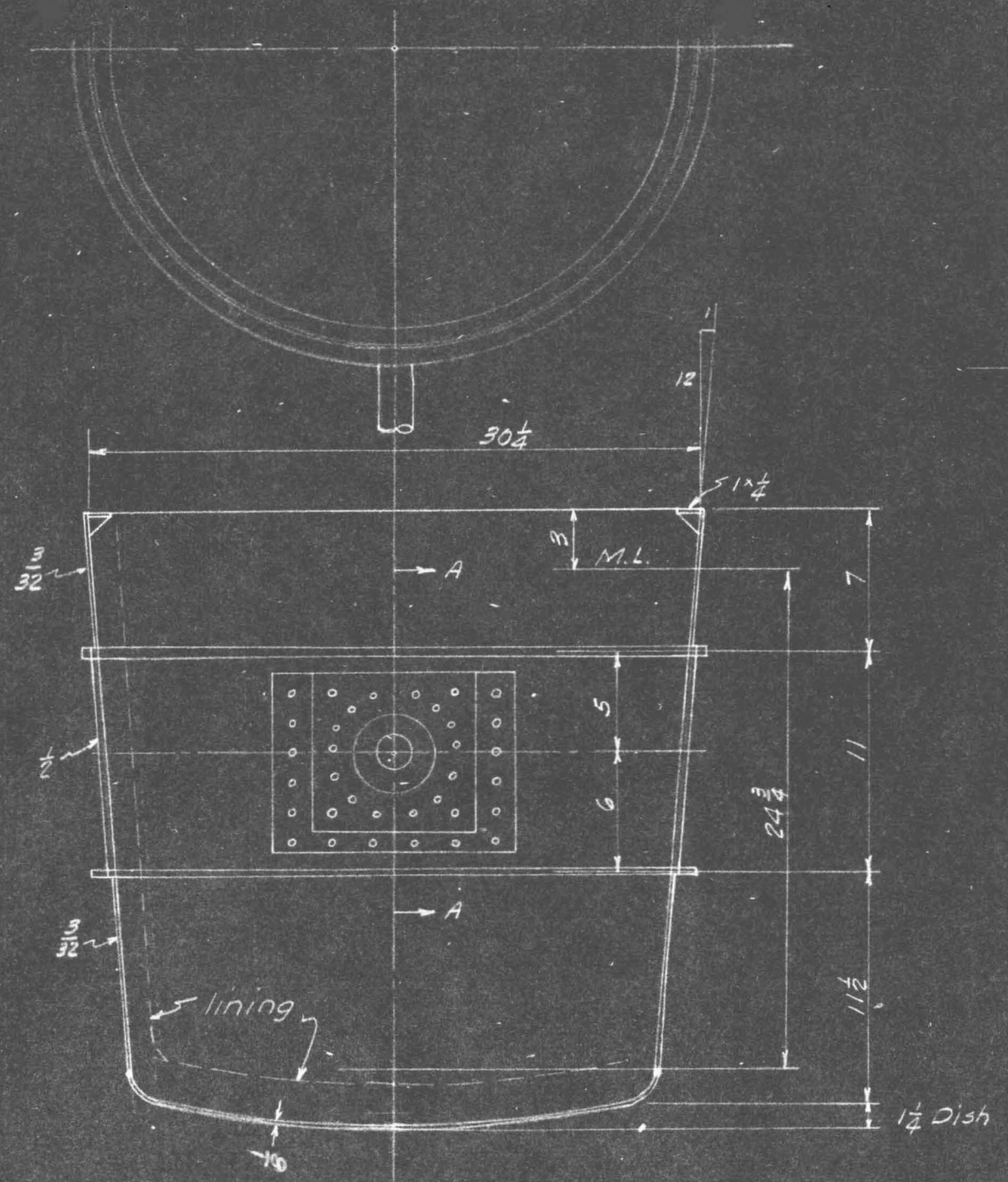
A.I. & S.E.
HOT METAL LADLES
SPECIMEN B

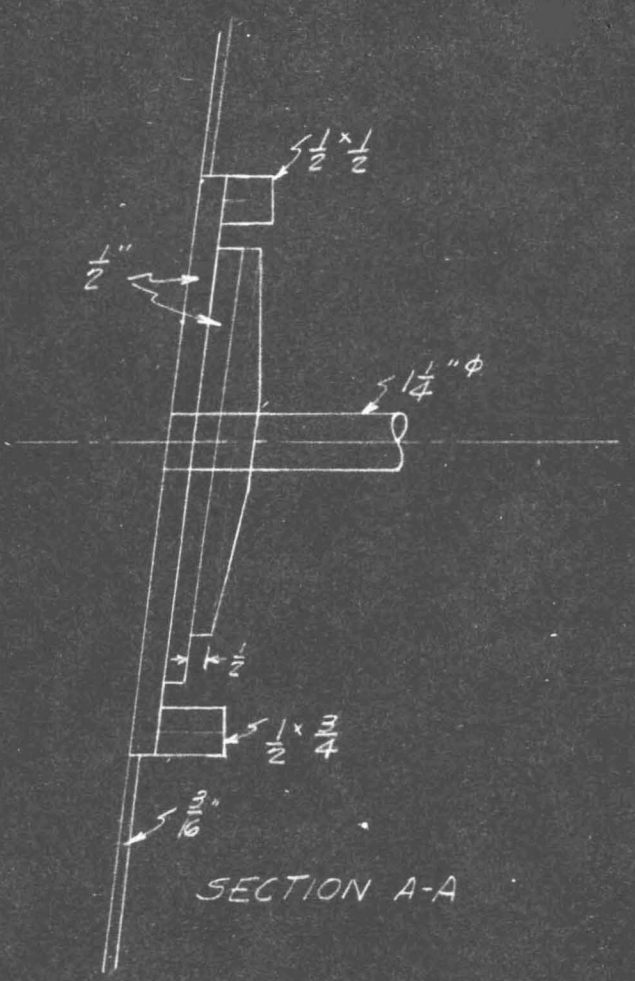
FIG. NO. 2.

Scale 1/8" = 1"

WHM

FL 202.3





SECTION A-A

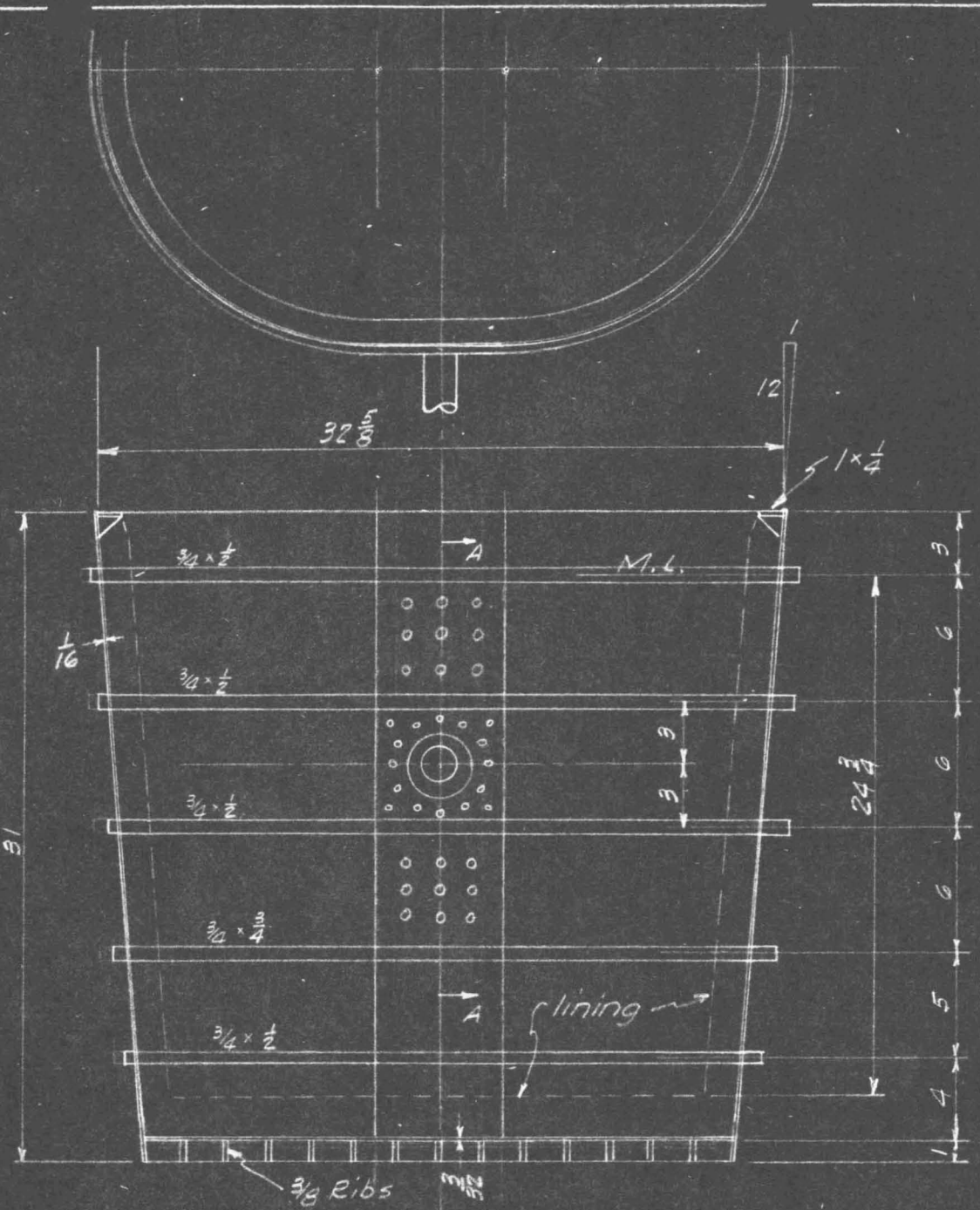
A. I. & S. E.
HOT METAL LADLES
SPECIMEN C

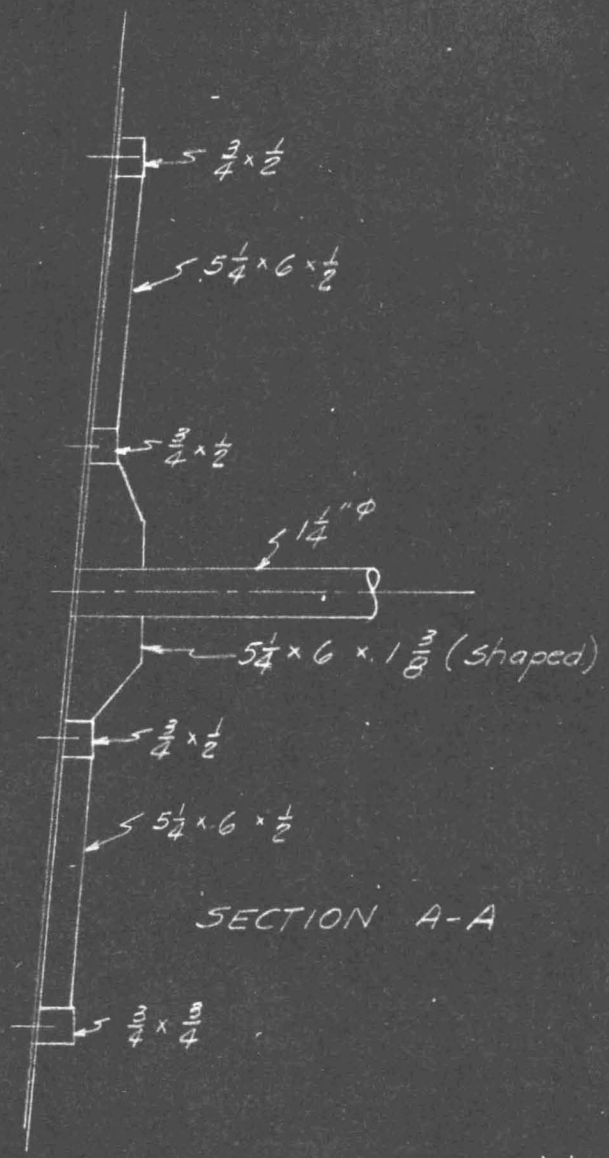
FIG. NO. 3.

Scale ⅛" = 1"

WHM

FL 8(.4





SECTION A-A

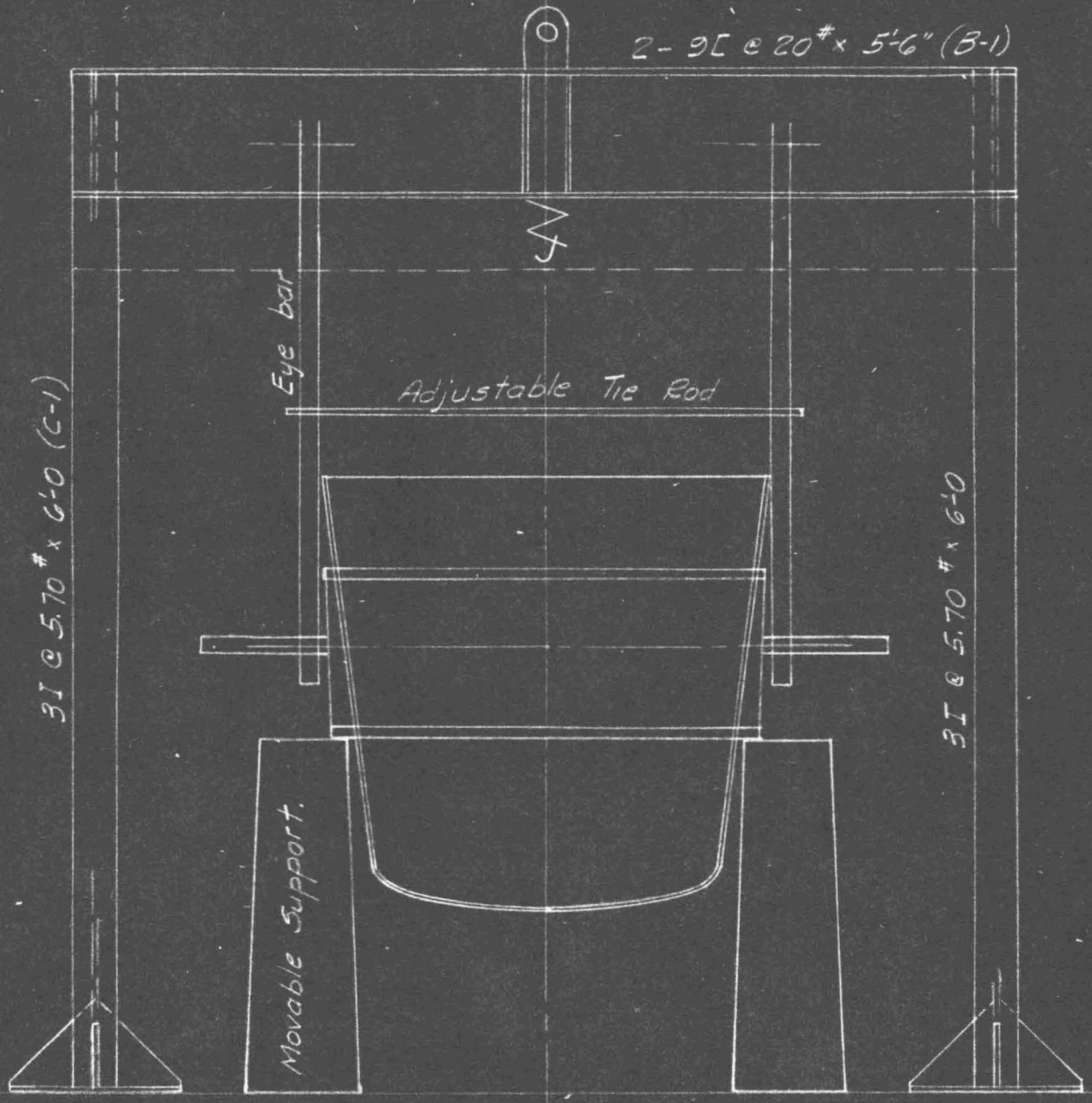
FIG. NO. 4.

A. I. & S. E.
HOT METAL LADLES
SPECIMEN D

Scale 1/8" = 1"

WHM

FL 202.3



GEN. NOTES

1. The beam (B-1) elevation shall be adjustable.
2. The distance c. to c. of eye bars shall be adjustable.
3. The columns (C-1) shall be anchored to the floor.
4. Jack to be placed at point J with Plug in ladle for loading.

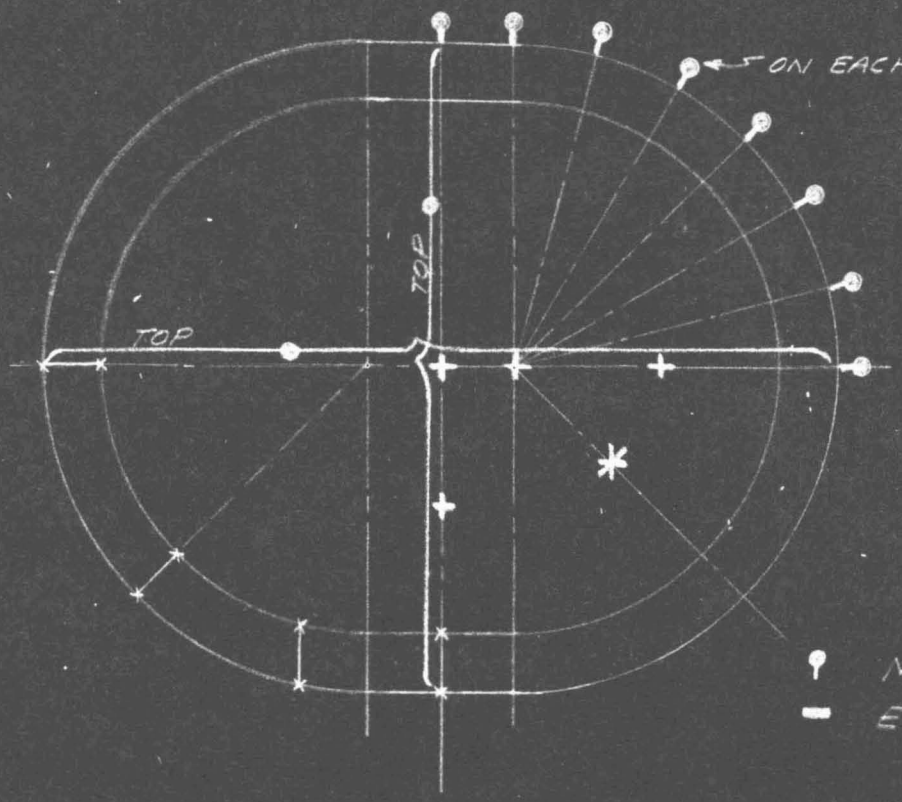
A. I. & S. E.
HOT METAL LADLES
TEST FRAME

FIG. NO. 5

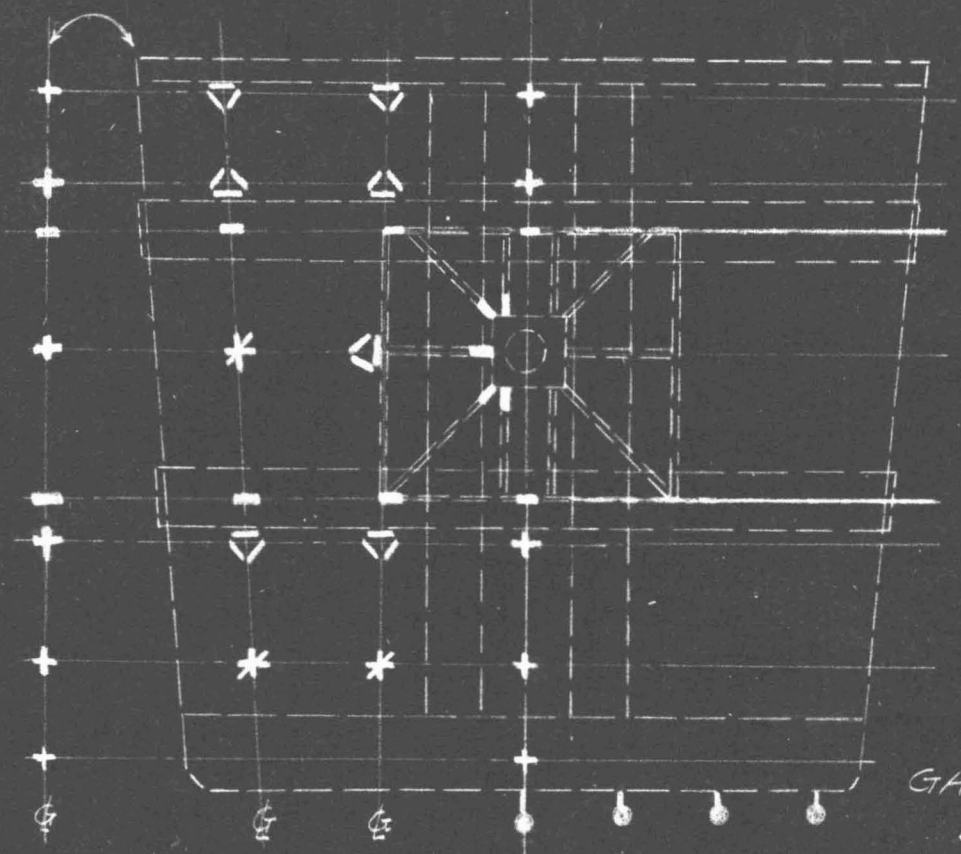
Scale 1" = 1'-0

WHM

FL 202.6



SYMBOLS
MECH. GAGES
ELECT. GAGES

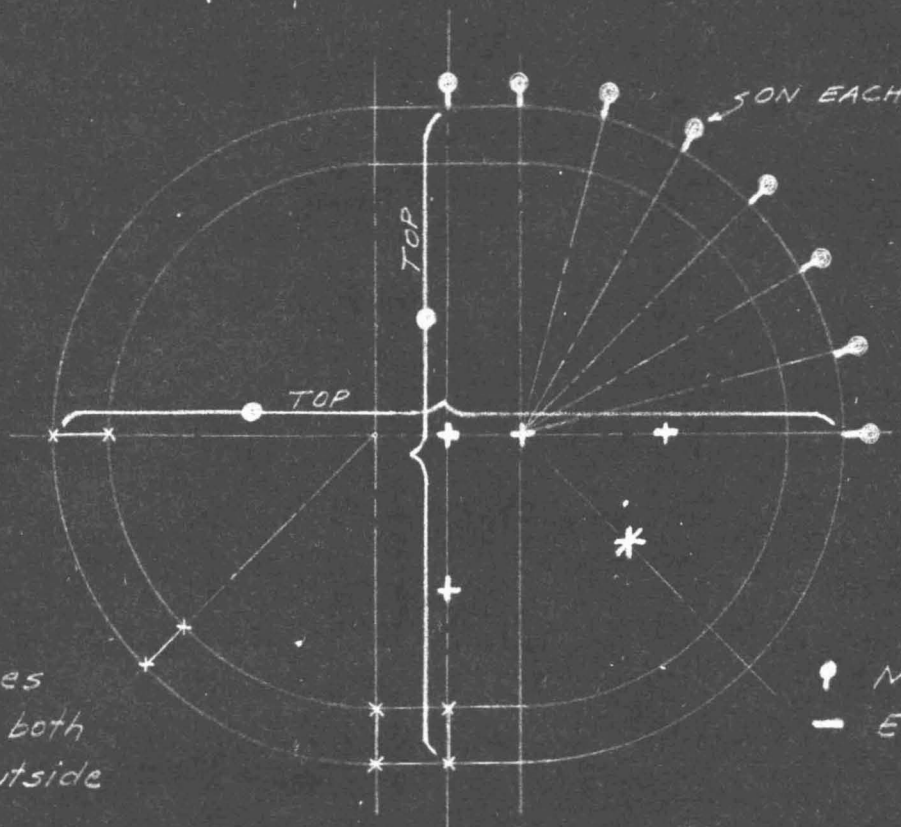


Identical gages on inside & outside

GENERAL GAGE LOCATIONS SPECIMEN-A

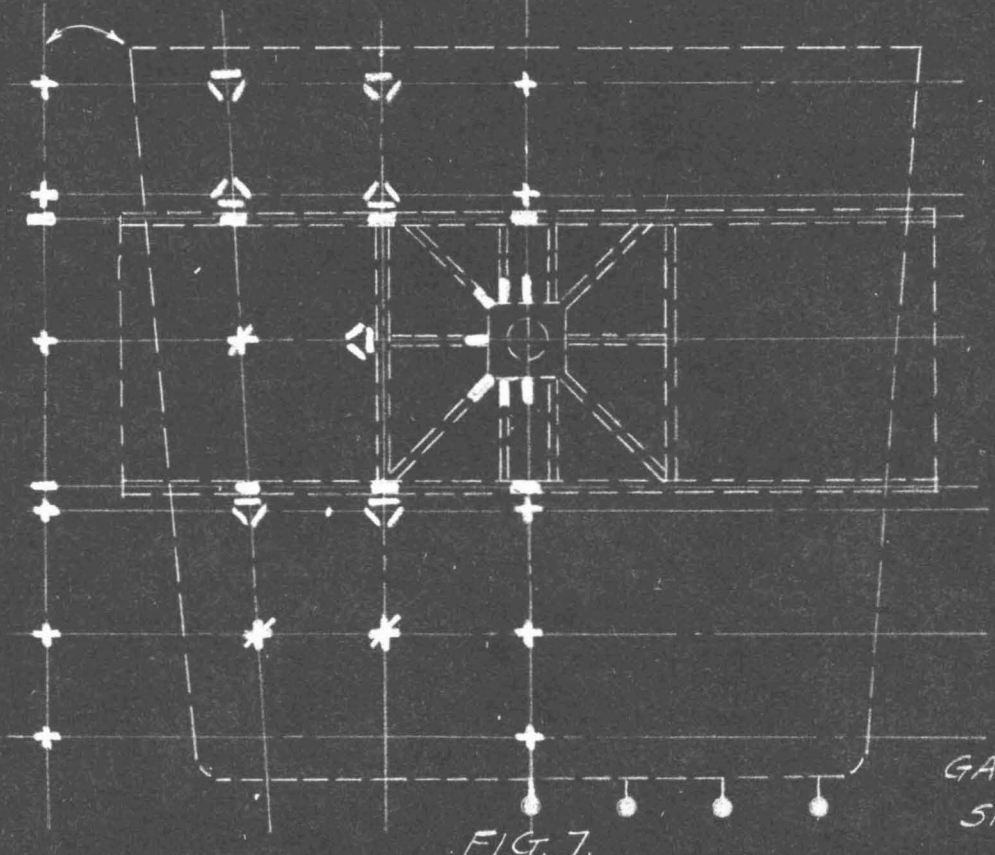
FIG. 6

FL 202.7



Identical gages to be placed both inside and outside

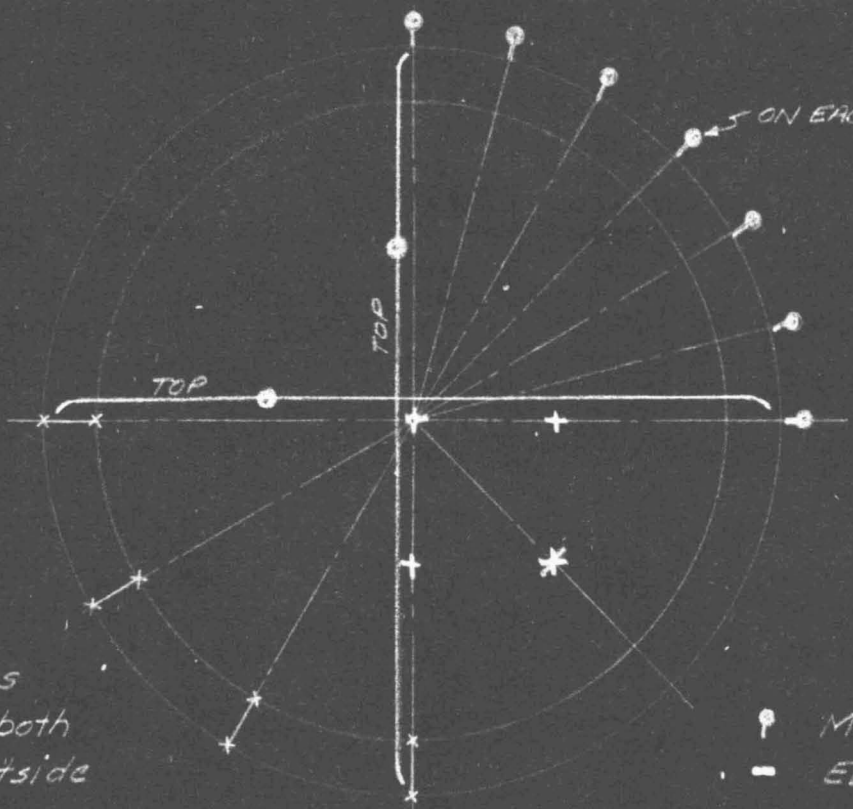
SYMBOLS
MECH. GAGES
ELECT. GAGES



GENERAL GAGE LOCATIONS SPECIMEN - B

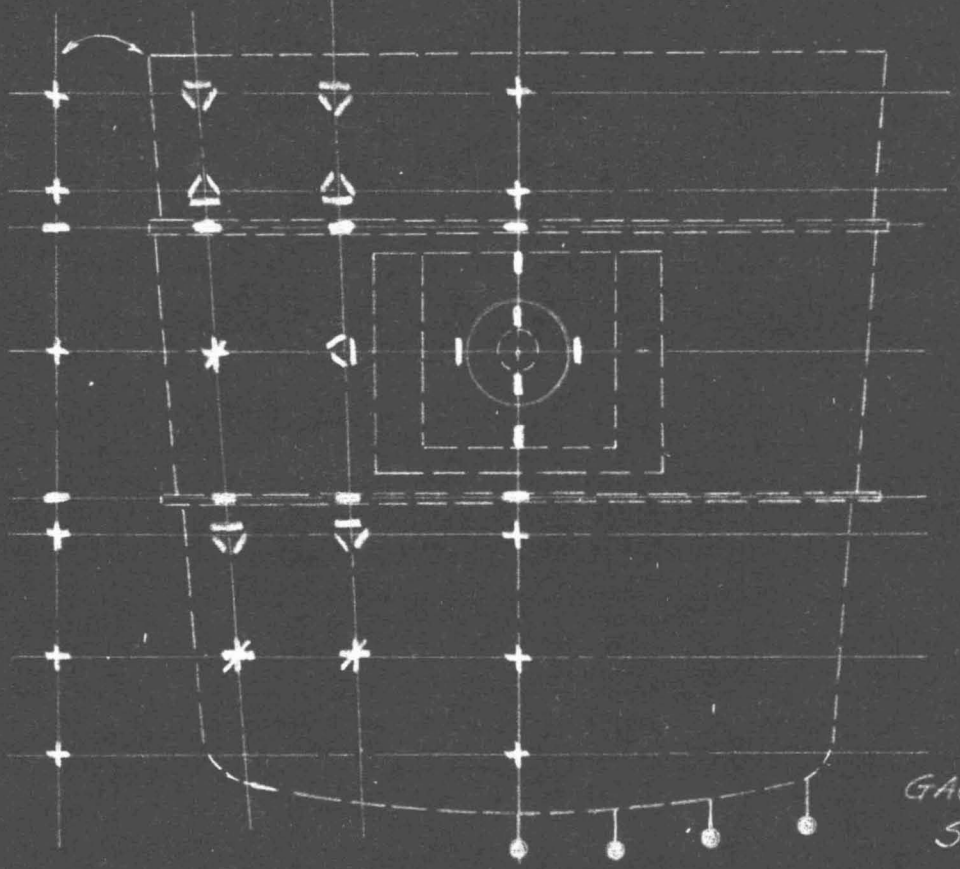
FIG. 7.

FL 202.8



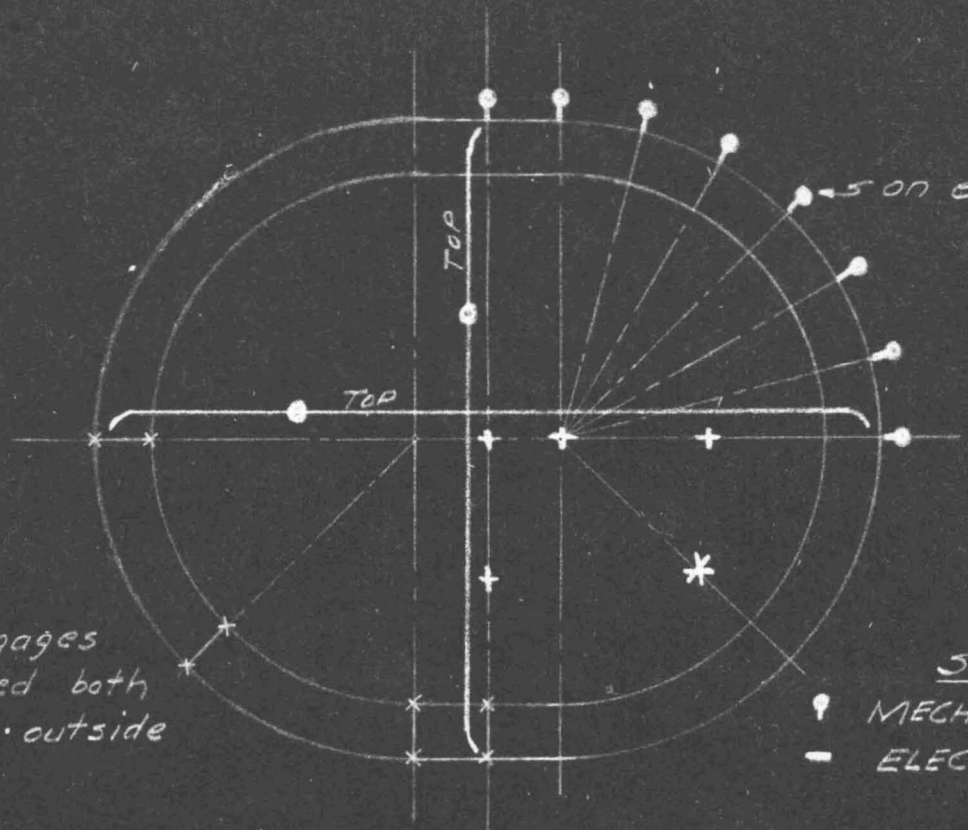
Identical gages to be placed both inside and outside

SYMBOLS
MECH. GAGES
ELECT. GAGES



GENERAL GAGE LOCATIONS SPECIMEN-C

FIG. 8



Identical gages to be placed both inside and outside

SYMBOLS
MECH. GAGES
ELECT. GAGES

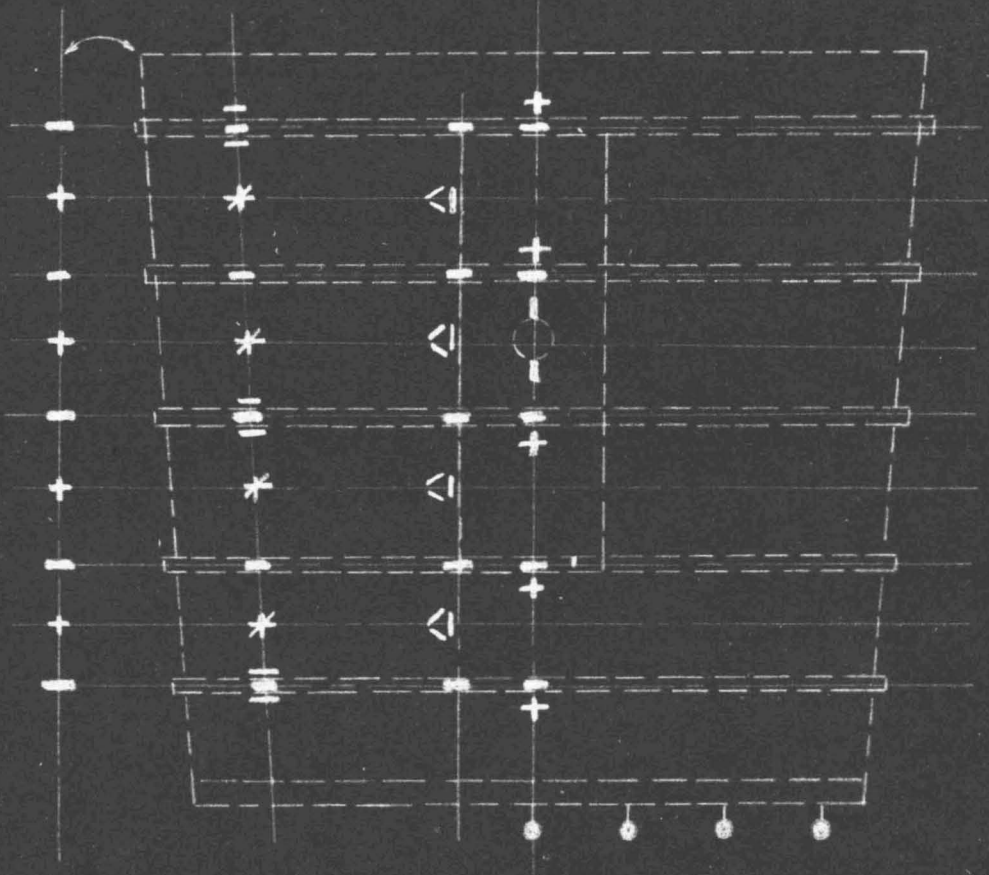


FIG. 9.

GENERAL GAGE LOCATIONS SPECIMEN-D